CLEAN COAL TECHNOLOGY DEPLOYMENT: FROM TODAY INTO THE NEXT MILLENIUM

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I. INTRODUCTION

The Department of Energy's clean coal technology (CCT) program succeeded in developing more efficient, cleaner, coal-fired electricity options. The Department and its private partners succeeded in the demonstration of CCT--a major feat that required more than a decade of commitment between them. As with many large-scale capital developments and changes, the market can shift dramatically over the course of the development process.

The CCT program was undertaken in an era of unstable oil and gas prices, concern over acid rain, and guaranteed markets for power suppliers. Regulations, fuel prices, emergence of competing technologies, and institutional factors are all affecting the outlook for CCT deployment.

I've been asked by the organizers to identify the barriers to CCT deployment and to challenge the speakers in Panel 4 to consider how these barriers might be overcome. Below, I discuss the major barriers, and then introduce some possible means to surmount the barriers.

II. BARRIERS

The growth in the market share for clean coal technologies will be driven by institutional/regulatory structure, environmental issues, and costs (both capital and fuel).

The demand for new capacity is addressed by another panel. Bechtel's capacity addition forecasts show that 95 percent of new coal-fired capacity will be built in two of our four geographic regions--1. Europe, Africa, Middle East and East Asia and 2. Asia Pacific (Table 1). The largest markets for coal-fired capacity within these regions will be India, China, and Indonesia, with markets also in Eastern Europe, and South Africa. Only one-third of world capacity additions will be coal-fired. Natural-gas-fired capacity is expected to be the technology of choice in North and South America, as well as much of Western Europe and the Middle East.

Institutional Barriers

Deregulation

Let's examine the institutional/regulatory issues in the US, where we've made the large investment in developing clean coal technologies, in the expectation that they would meet a significant need in the US.

Today, the market for new capacity additions in the US is not large. The major political factor influencing the US electricity market is deregulation. Uncertainty over the impact of deregulation on utilities is causing them to postpone many capacity additions. In addition, deregulation affects the independent power producers, while they await the impact of deregulation on issues such as future cost recovery.

Deregulation of the US market will lead to a big market shake-up during the next five to seven years. A larger number of players have entered the market in the past few years and more are likely to follow, leading to increased competition in the near-term. It will be a buyers' market--increased competition disfavors longer-term purchase agreements. Under such market instability, suppliers won't commit to building large coal-fired power plants (>400 MWe). Even if a supplier wishes to build one, without an assured long-term market, the supplier is unlikely to get external financing. The market outlook will certainly be too risky to use equity financing. The independent power producers have already exploited most of the desirable sites for coal-fired power plants (e.g., next to a large industrial user). Easily installed capacity in modest sizes (i.e., gas turbines) will be the technology of choice in early phases of deregulation.

In the later stages of deregulation, competition could result in large generators' (i.e., utility) mergers, and a shake-out of IPPs, meaning there would be fewer suppliers in the market. However, technology choice might also begin to affect the market, i.e., centralization versus decentralization. For example, continued progress in "mini" turbines, fuel cells, and alike, could allow businesses, housing complexes, and even homes to have a power plant in their basement, which might be a very attractive choice if the power quality problems (expected to occur with deregulation) don't get solved.

Deregulation is spreading. In Western Europe, the United Kingdom is privatizing their power market, and new players (such as North Sea oil and gas producers) are entering the market (although new, coal-fired power plants are still being built, as well.). The extensive deregulation occurring in the US may well spread to other OECD countries, assuming there are positive results from US deregulation.

Other Institutional Factors

In the two largest markets, India and China, institutional factors can affect capacity choices in other ways. In India, regulations are quite specific to individual states.

Building a standardized power plant in several states may be difficult, which can pose barriers to building optimized, inexpensive (i.e., standardized) CCT plants.

World Bank financing, a common source in India, can favor CCTs, by requiring that environmental factors be taken into consideration for capacity choices.

China prefers to build its own boilers and other components, which will favor cheap, simple technology, a barrier to CCT. However, outside financing and international institutions could accelerate the adoption of local regulations that would promote the use of CCT.

Growing developing country markets pose a problem to national governments as well as outside investors. Despite the rationalization of prices encouraged by development banks, there is still a tension between increasing the standard of living by providing cheap electricity versus recovering full costs in major capital investments. Perceived political risk in certain countries will also disfavor large, fixed, capital investments in one country by outside investors.

Environmental Barriers

As stated earlier, the CCT program was undertaken when acid rain was a major concern, especially with respect to burning higher sulfur coals. The clean coal program successfully demonstrated virtual elimination of precursors to acid rain. Today, global warming has emerged as a major environmental driver. Carbon dioxide is seen by the public and some of the technical community as the key component in global warming. Carbon dioxide emissions has therefore become one of the biggest technical challenge to future, environmentally-benign coal consumption .

Coal-fired electricity generation releases relatively more greenhouse gases than does combined-cycle, combustion-turbine technology (CCCT). However, the efficiency increases of CCT will decrease CO2 emissions significantly, relative to standard coal technologies, such as atmospheric fluidized bed combustors. Therefore, CCT certainly helps with the greenhouse gas problem resulting form coal consumption, but doesn't solve it as shown in Table 2.

If the international community ever agrees upon greenhouse gas emissions quotas, the quotas could encourage use of CCT relative to conventional coal capacity, but perhaps generally discourage coal use, relative to natural gas use.

The joint implementation (JI) program is off to a rather weak start. JI could, however, subsidize CCT in developing markets, where the technology of choice might have been conventional coal technology. JI could also favor more natural gas technology, however.

Repowering and retrofitting have been proposed by many as one of the solutions to revitalize the aging US power industry. However, there are other environmental considerations that affect the market for CCT. Environmental regulations in the US discourage retrofits of coal-fired power plants. For example, retrofitting a plant makes it subject to updated emissions requirements, and also requires asbestos removal, etc. These regulations/environmental factors discourage retrofitting older coal-fired capacity with new CCT.

Cost Barriers

Table 3 shows Bechtel's projections of levelized life-cycle cost per kilowatt hour for a number of electric generating technologies. The figure demonstrates that cost poses a significant barrier to CCT adaptation, even though the cost of CCT could approach that of conventional coal-fired generation on a levelized life-cycle cost basis.

Capital Costs

The capital costs of coal technologies are at least twice the capital costs of CCCT (i.e., 2.2 to 2.9 c/kwh for coal-fired capacity compared to 1.1 c/kwh for CCCT). From a front-end investment standpoint, the cost of coal-generation certainly disfavors coal-fired capacity relative to gas-fired generation. Capital investment is also the major factor in choosing capacity type if outside financing is sought.

The near-term potential to decrease the capital cost for CCT lies in system optimization (e.g., be less conservative in redundant systems while maintaining reliability). Total system optimization can be difficult to achieve until a number of CCT plants are built, however. Even then the system optimization improvements won't halve CCT capital costs. If one expands the definition of "system" from the power plant components to a more expanded system, including fuel production, delivery, combustion, and electricity transmission, there are further economies to be captured. Whether this integrated energy system based on coal can compete with integrated systems based on natural gas remains to be seen.

The longer-term potential to decrease CCT capital costs will come from new technologies, such as ceramic membrane technology to decrease the cost of oxygen production for technologies that can benefit from an enriched oxygen source, such as IGCC. Unless we invest in these developments, however, these new technologies won't be built.

O&M Costs

O&M costs (excluding fuel) are not major differentiators for the capacity choices. The further development of "smart" operating systems are likely to further decrease the costs of running electric generators. This enhancement should benefit all technologies, but CCT, which tend to be more complex, should benefit more.

Fuel Costs

Fuel costs are relatively a much larger component of the total cost of electricity from natural-gas fired plants than they are for coal. In the absence of any decrease in capital costs, natural gas costs would have to increase significantly for a sustained period to " level the playing field" (on a levelized life-cycle cost basis) between CCCT and CCT. Natural gas costs would have to increase by about 50 percent (about $1.5 per MM Btu) relative to coal to make CCT competitive with CCCT. The natural gas price increase would have to be sustained. However, long-term natural gas price expectations generally are fairly flat. Deployment of advanced natural gas processing technologies (e.g., Fischer Tropsch) could help ensure natural gas price stability at current levels. This outlook for natural gas prices makes CCCT hard to beat on a life-cycle-cost basis, except in markets with an abundance of cheap coal and/or wastes for combustion in CCT.

III. CHALLENGES TO MARKET INTRODUCTION OF CCT

The foregoing has demonstrated the significant barriers that are presented for the widespread introduction of CCT. The question then is how does one make coal more competitive with its fossil competition? How can widespread market introduction be accomplished? This can be done by looking at the differences between coal and the alternatives and developing strategies to minimize these. The challenges below are technical ones; an alternative or complementary approach is to pursue regulatory or policy changes to effect some of the institutional barriers outlined above.

Make Coal "Look" Like Other Fossil Fuels

The variability of coal makes it difficult to take full advantage of standard plant designs (which are the cheapest). Therefore, one needs remove, as much as possible, the differences among coals of equal rank. This entails beneficiation, washing, etc. Coal blending is one method already being practiced in some cases to improve plant availability and stabilize sulfur control systems.

An additional consideration is that natural gas and oil are delivered by suppliers in an integrated manner. Therefore, we need to use an integrated, systems approach to coal preparation and delivery (mining, grinding, cleaning, transport, and the method of utilization), i.e., break apart the old "silo" approach among mining firms, transportation (railroads), and utilities/IPPs. Coal-water slurries are one example of such integration. CCT's, such as IGCC and PFBC have already demonstrated the ability to use slurries to feed coal at high pressure.

Improve Coal's Environmental Performance

The most important need here is to increase the overall efficiency of coal utilization thereby decreasing the pollutant unit per kwh or per ton of coal. As stated earlier, CCT have increased efficiency, but current initiatives by DOE, included in Combustion 2000 (and other programs) will further increase the fuel efficiency for pressurized, fluidized bed combustion, IGCC, and other CCT.

Removing coal variability as proposed above also enables more of a standardized approach to CCT. CCT is fairly flexible, for example, with minor design changes it can handle coals range from 1 to 4 percent sulfur and beyond. Further fuel flexibility could improve plant standardization.

"Blending" coal with other fossil fuels can also mitigate environmental impact. Blending can be done in a dual fuel approach or in an incremental approach as noted below. The use of natural gas in the pressurized fluidized bed topping cycle is an example of blending that improves environmental performance.

Reduce Costs on a Net Present Value (NPV) Basis

For certain technologies, we could look at how the plant can be built for dual-fuel capability in one of two ways. The first approach is to build a CCCT plant leaving space to add coal handling equipment to convert to coal as fuel prices change. The second approach is to build the plant for dual-fuel capability right from the start and mix and match as fuel prices and national interests dictate. The latter approach is a variant of the solar hybrid concept (in reverse).

Another way of improving the NPV is through environmental subsidies, i.e., recognizing that the use of indigenous fuels is desirable, but that such fuels (coal) are only competitive in the current market if environmental pressures are relaxed, a policy could be developed which would give incentives for the use of state of the art CCT. Such incentives may be provided by the Global Environment Facility, or other lending agencies involved in the country under question.

Yet another way to incrementally improve the NPV of CCT is by developing a market for the CCT with low-price fossil fuels other than coal, i.e., heavy oils, petroleum coke, orimulsion, biomass, etc. This expansion of the market for CCT could speed plant optimization. A recent announcement by GE and Toshiba that they plan to partner to market IGCC technology demonstrates this approach. Under the agreement, GE and Toshiba expect to furnish the turbine-generator equipment, and to broaden their IGCC market penetration.

IV.   CONCLUSION

The implementation of clean coal technologies will be difficult for a variety of reasons as we have seen. Innovation and new approaches to commercialization, standardization, and improved environmental performance are keys to more widespread use in the next millenium.

Table 1. Regional capacity additions in gigawatts (based on orders, 1997-2002)

	Total	Natural Gas	Coal-fired	Nuclear	Hydro
North America	46	39	4	-	3
Europe, Africa, and East Asia	124	87	27	6	4
Asia Pacific	165	36	95	24	10
Latin America	57	26	2	1	28

Table 2. Relative Levels of CO2 Contributed to Greenhouse Emissions

	GTCC	PCF w/ FDG	AFBC	PFBC	IGCC	APFBC
Power, MWe	500	500	500	500	500	500
Heat Rate, BTU/kW	8030	10040	10190	8320	7940	7190
Efficiency, %	42.5%	34.0%	33.5%	41.0%	43.0%	47.5%
Fuel Heat Content, MM Btu/hr	4,015	5,020	5,095	4,160	3,970	3,595
Fuel	Nat Gas	Coal*	Coal*	Coal*	Coal*	Coal*
Heat Content, Btu/lb	23,840	13,260	13,260	13,260	13,260	13,260
Fuel Feed, lb/hr	168,410	378,580	384,240	313,730	299,400	271,120
Carbon, lb/hr	126,310	279,390	283,570	231,530	220,960	200,090
Sulfur Content, lb/hr	0	7,950	8,069	6,588	6,287	5,694
Ca/S	0	1.01	2.6	1.3		1.9
Limestone required, lb/hr	0	26,690	69,750	28,470	0	35,960
CO2 from Fuel	463,140	1,024,430	1,039,760	848,940	810,190	733,660
CO2 from Limestone	0	11,740	30,690	9,640	0	8,330
Total CO2	463,140	1,036,170	1,070,450	858,580	810,190	741,990
Normalized of AFBC	43.3%	96.8%	100.0%	80.2%	75.7%	69.3%

* Based on Pittsburgh Seam Coal

Table 3. Levelized lifecycle costs for alternative electric generating technologies

400-600 MW range

	PC (steam coal)	CCCT (nat. gas)	PFBC (waste/low grade coal)	IGCC (waste/low grade coal)
Capital c/kWh	2.2	1.1	2.6	2.9
O&M c/kWh	0.6	0.4	0.6	0.9
Fuel c/kWh	1.2-2.2	2.0-3.4	0.6-1.2	0.5-1.0
- based on deliv'd $/MMBtu range:	1.50-2.50	2.50-3.80	0.60-1.20	0.60-1.20
Total lifecycle busbar cost	**4.0-5.2**	**3.5-4.9**	**3.8-4.6**	**4.3-4.8**

1400 MW range

	LNG CCCT	Nuclear ABWR
Capital c/kWh	1.6-1.2 (2x1400 MW)	4.5-4.0 (2x1400 MW)
O&M c/kWh	0.5	1.0
Fuel c/kWh	2.5-3.3	0.6
- based on deliv'd $/MMBtu range:	3.50-4.50	0.60
Total lifecycle busbar cost	**4.2-5.4**	**5.6-6.1**

Note: The cost competitiveness of these technologies will depend for a large measure on local fuel availability and pricing. Fuel is the most widely varying cost factor for all technologies except nuclear.